FAA In-flight Icing/Ground De-icing Conference
Chicago June 16 – 20, 2003

COMPARATIVE RISKS
of
VISUAL vs SENSOR BASED INSPECTION

Background:

Accident investigations have highlighted the need to provide pilots with a means to assess the external state of the aircraft from within the flight deck.

Regulations require PIC to perform inspection prior to takeoff during winter precipitation (note: exception).

Point and remote sensors have been developed capable of identifying the presence of frozen contamination on the aircraft critical surfaces.

HoldOver Times correlate with presence of some level of contamination on wings.

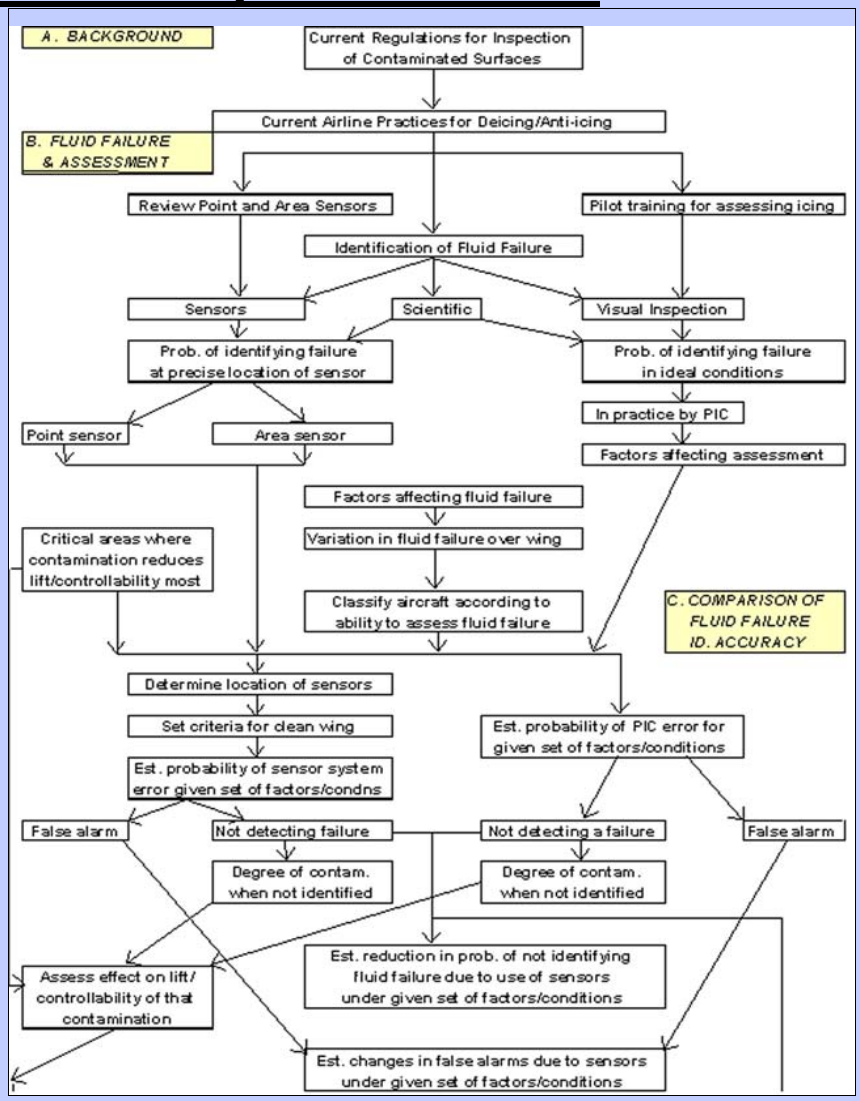
- Transport Canada initiated a study in 1997 to compare the risks of sensor vs visual inspection.

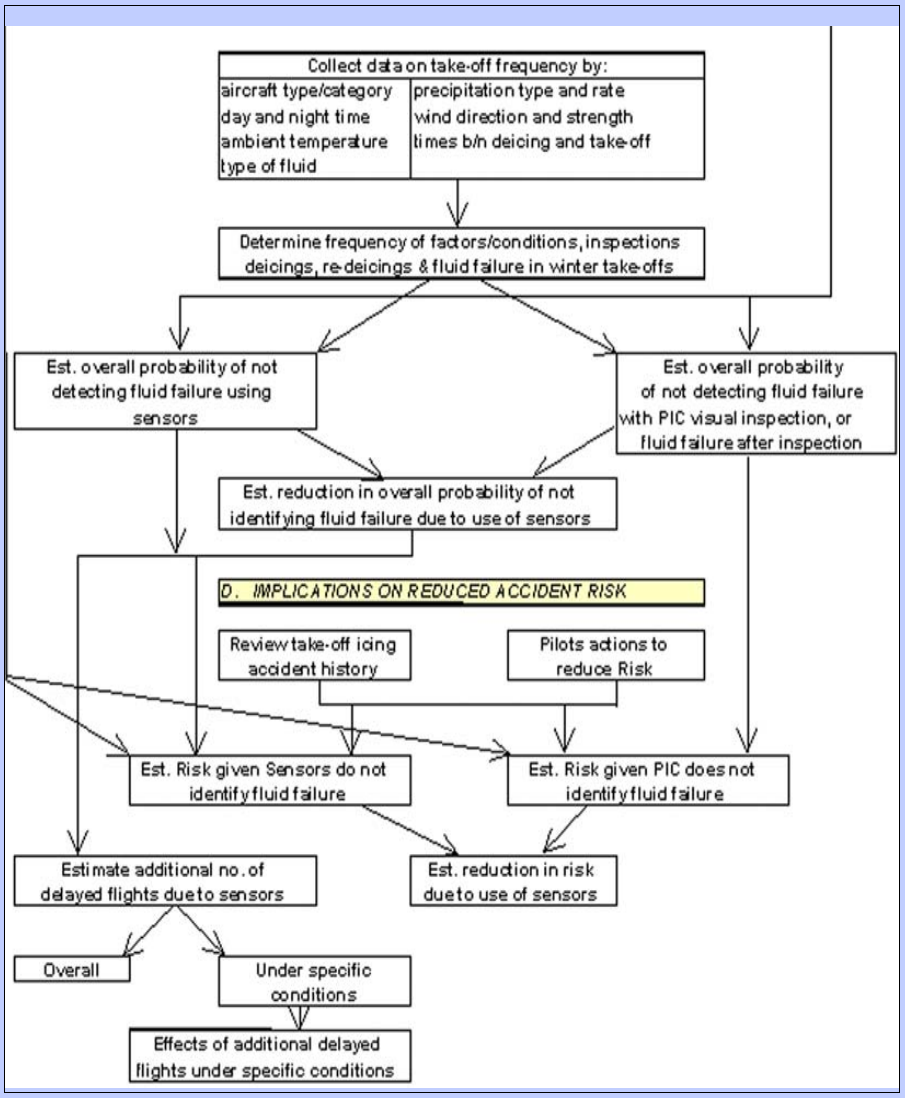
Comparative Risks of Visual vs Sensor Based Inspection (Refs: TP13267E & TP13427E)

Study Methodology:

- **Review Current Regulations and Airline Practices.**
- **Review Human and Sensor Characterization of Fluid Failure.**
- **Compare Accuracies of Human and Sensor Failure Identification Accuracy.**
- **Evaluate Comparative Implications for Accident Risk.**

Risks analysis flowchart:

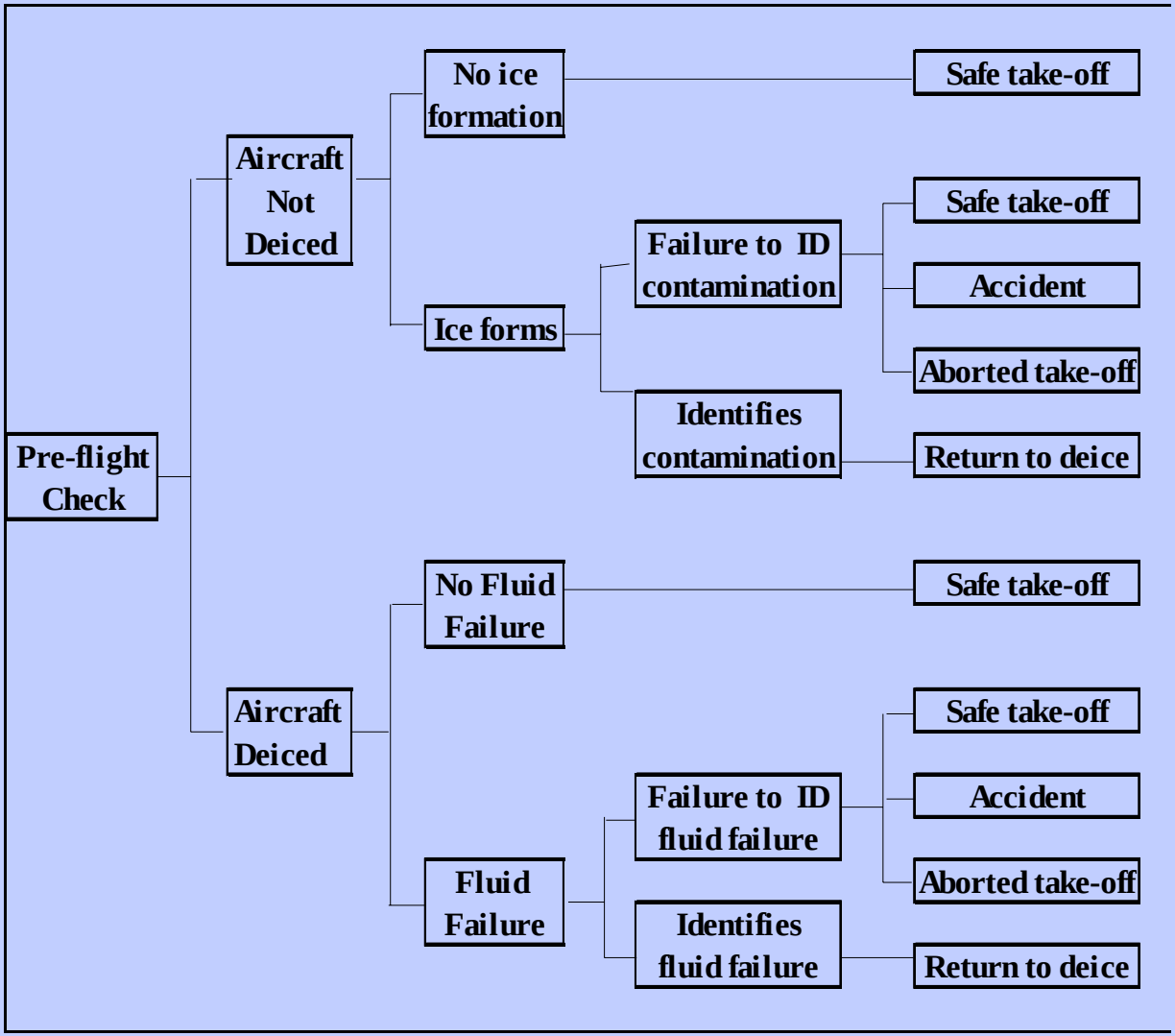




Sample Event Sequence:

Sequence of Critical Events	Principal Factors Affecting Critical Events
Fluid failure	Fluid type and application Ambient temperature Precipitation type & rate Wind speed & direction Aircraft type, wing temperature
Failure to identify fluid failure	**Visual**: Visibility, Aircraft type **Sensor**: Wind, Aircraft type, Sensor capabilities
Aircraft take-off	Delay time after deicing
Aircraft stalls/crashes	Aircraft type Degree of wing contamination Aircraft load Pilot reaction
Fatalities/injuries Property damage	Aircraft type Terrain Pax onboard

Sample Risk Analysis Tree:

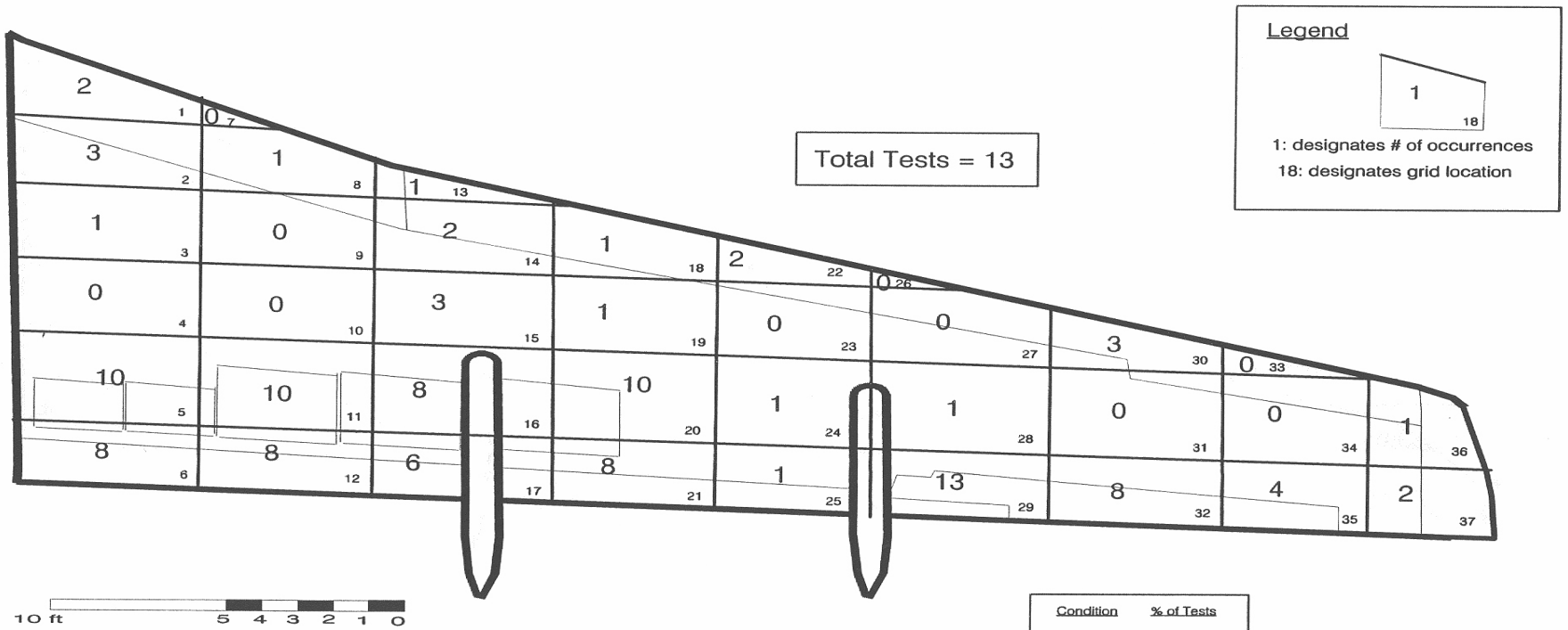


Sample reference data developed -

FIGURE 3.17

OCCURRENCES OF FIRST WING FAILURE BY WING GRID LOCATION

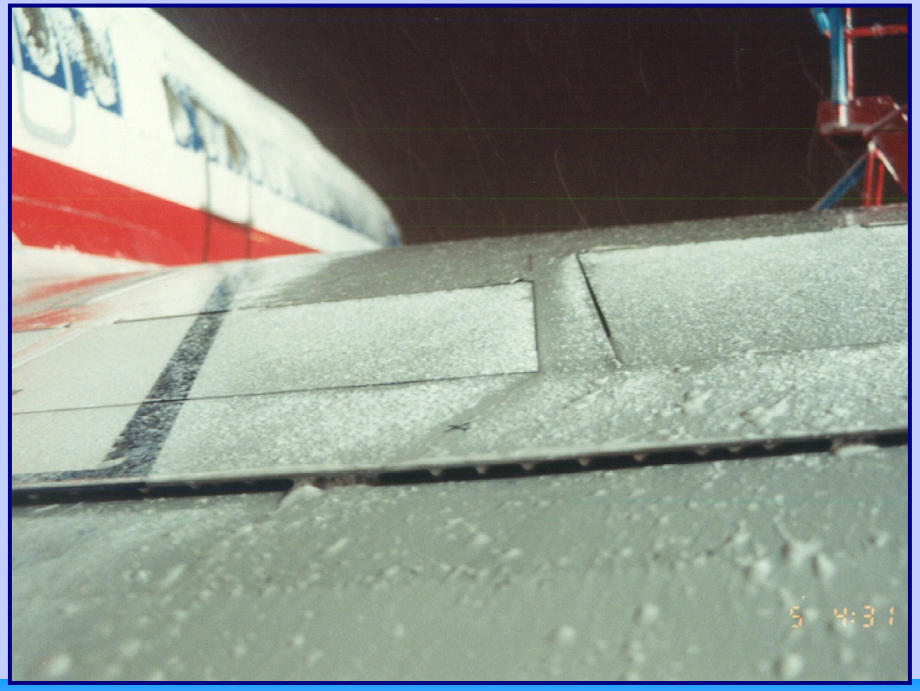
FOKKER 100



Condition	% of Tests
Head Wind	23%
Cross Wind	31%
Tail Wind	46%

Note: Occurrence was counted when any amount of failure was present in the grid

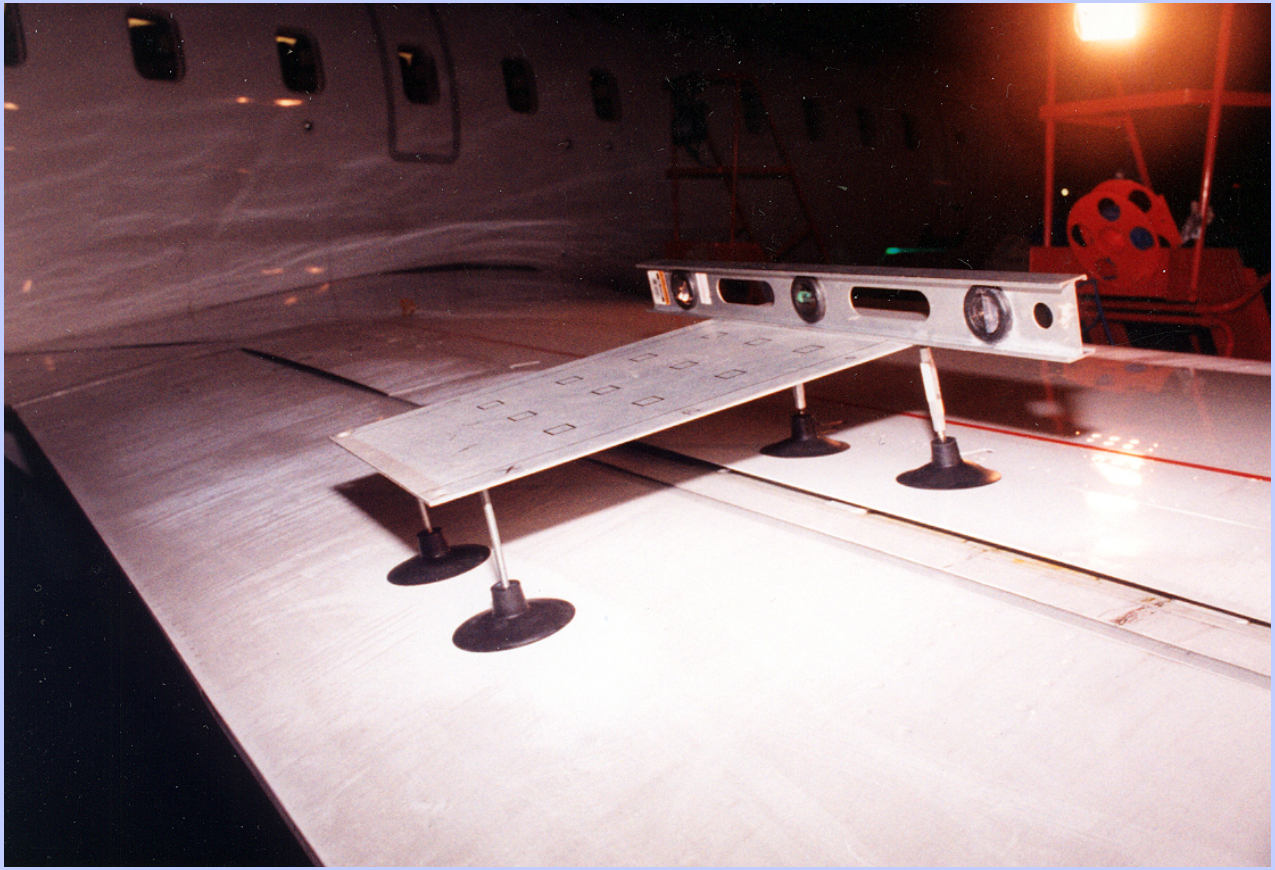
Fokker F-100: Fluid failure, exposed to snow



Sample data – pattern of fluid failure, hard wing aircraft. Snow, Canadair CL65 (RJ)

Sample reference data developed - fluid failure pattern: snow precipitation on a Boeing 737:

Set-up for Wing condition evaluation at end of HOT:



Sample reference data – Survey of ~700 Canadian & 1570 US Pilots:

Re: HoldOver Times

- **Pilots have confidence in the HOT's – they find the ranges given are more useful than a single value**
- **Most pilots are conservative; they use the HOT's; when in doubt they return for de-icing.**
- **Most pilots rarely exceed the HoldOver Time (HOT), rarely see fluid failure, do not know what a failing fluid looks like, and do not receive suitable training.**

Failed fluid in Freezing drizzle: not visible from cockpit. Failure highlighted by directed external lighting. (DC9)

Sample reference data – Survey of ~700 Canadian & 1570 US Pilots: **Re: Sensors**

- **Pilots feel that sensors would improve safety, *provided* that they are accurate and reliable; are an aid to visual checks, and give a "No Go" indication.**

- **Delay between pre-takeoff check and takeoff averages 2.5 – 3.5 minutes, occasionally requiring 5 minutes.**

NOTE: Type I fluid failure can spread from a small local patch to full wing coverage in under 5 minutes.

Principal Study Findings:

- No single number quantifies probability of an accident unless a specific scenario is selected.
  Most accidents involve more than one causal factor.
- Sensor operation is continuous,
  pilot checks are intermittent.
- Two point sensors, properly located, per wing reduce risk by 1.5x to 50x, subject to operational conditions.
- Three point sensors per wing reduce risk by a further 30% to 50%.
- Visual + sensor based inspection is significantly safer than separate inspection procedures.
- Use of sensors would reduce unnecessary re-deicing.

Issues to be addressed:

- **Lack of detailed Sensor Standards.**
  This issue addressed since the study conducted – SAE 5116/EUROCAE ED104 has been developed.

- **Absence of defined operational thresholds – current regulations require that critical surfaces are free from adhering contamination at time of aircraft takeoff.**

- **Inadequate data available to draw conclusions for potential use of remote sensors for pre-takeoff inspection.**

Threshold considerations (1):

- **SAE 5116 threshold for a sensor *to qualify as a Ground Ice Detection System:***
  0.5mm thickness on 315cm^2, 0.020” on < 50 in^2.
  This is NOT a regulatory threshold
- **Detection of adherence not presently practical**
  - if frozen contam^n identified, assume it adheres.
  - Regulations effectively set threshold for ground ice detection at zero - not realistic for sensor design.
- **True safety criteria: ensure aerodynamic clean surfaces. Some contamination might be acceptable if there is *no significant* impact on lift, drag, or control.**

Threshold considerations (2):

- **Ground ice contamination can be characterized as a roughness effect on aerodynamic performance.**
- **Low levels of distributed roughness on wing leading edge cause major penalties.**
  e.g. 3m chord wing with the leading edge contaminated back 5% of chord with 0.3mm deep frost
  → max lift reduced by 10% or more.
- **Recent theoretical and Wind Tunnel studies by Transport Canada show local patches of slush consistent with the onset of fluid failure, and at sensor thresholds may have only a marginal effect on wing performance.**
  – possibly less than the effect of clean fluid.
- **Studies, including flight test are on-going.**

Remote Sensor Applications:

(1) Pre-takeoff inspection

- **Tests have now been conducted to demonstrate technical feasibility of conducting pre-takeoff inspection using remote sensors.**
  – a sensor 'Zoom-in' capability will probably be required.

- **Application for pre-takeoff inspection requires resolution of the threshold issue.**

Remote Sensor Applications:

(2) Post de-icing inspection

- Sensors are faster, more consistent and view larger wing area compared to tactile inspection.
- Residual ice below threshold level is smooth due to Type I fluid heat.
- Note that ½ % to 1% of aircraft subject to tactile inspection, conducted after visual inspection, are found to require re-deicing.

It is reasonable to assume that ½% to 1% of aircraft subject to visual inspection only, leave the pad with contamination present!